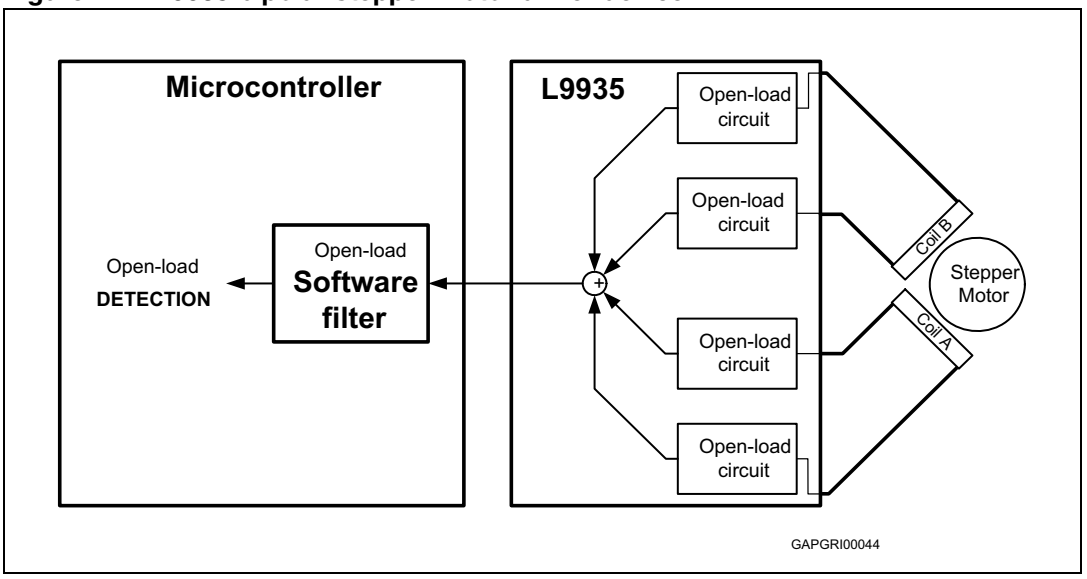
AN2378
Application note

Software filter algorithm for open-load detection on the L9935 device

Introduction

This document describes a software algorithm used for detecting an open-load condition. The algorithm refers to the L9935 two-phase stepper motor driver. The algorithm identifies the open-load failure within the failure class and filters out occurrences of false open-load failures.

Figure 1. L9935 bipolar stepper motor driver device



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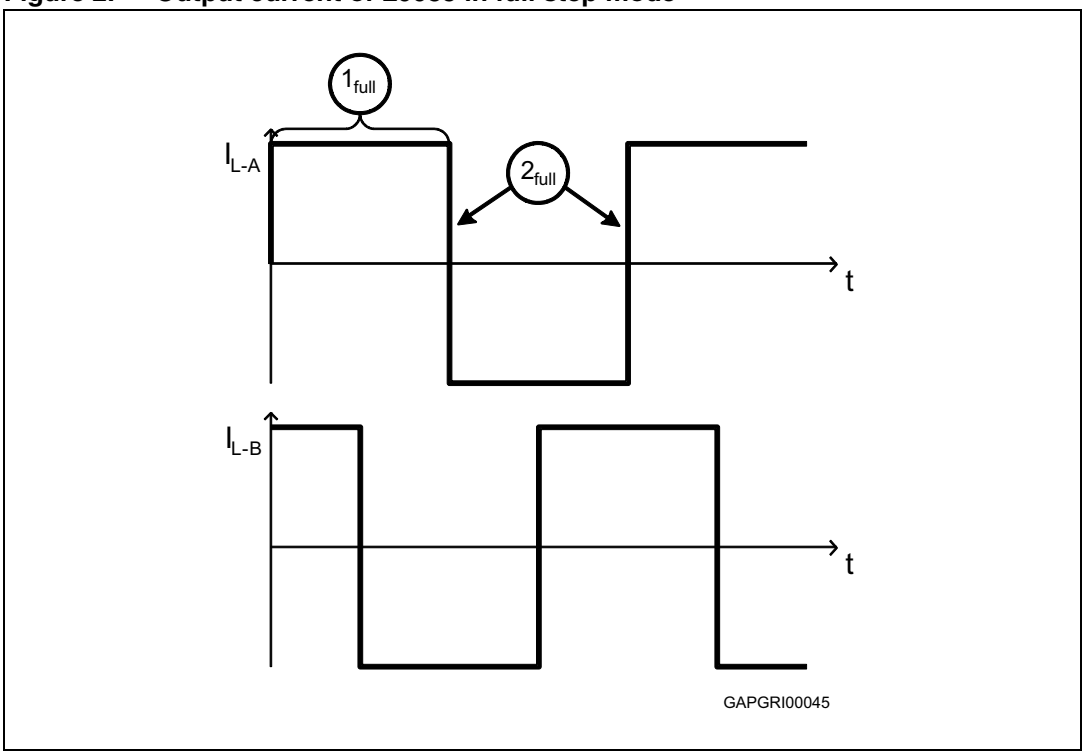
1 When does L9935 open-load checking occur?

The flyback pulse indicates the availability of an inductive load. The flyback pulse is checked after reversing the polarity of the motor current (full step mode), namely 61% I_{shunt}[(a)] or 100% I_{shunt}, or after changing the current from 61% I_{shunt} to 0% I_{shunt} (half step mode) (please refer to L9935 datasheet; see *A.1: Reference documents*).

1.1 Full step mode

Figure 2. Output current of L9935 in full step mode



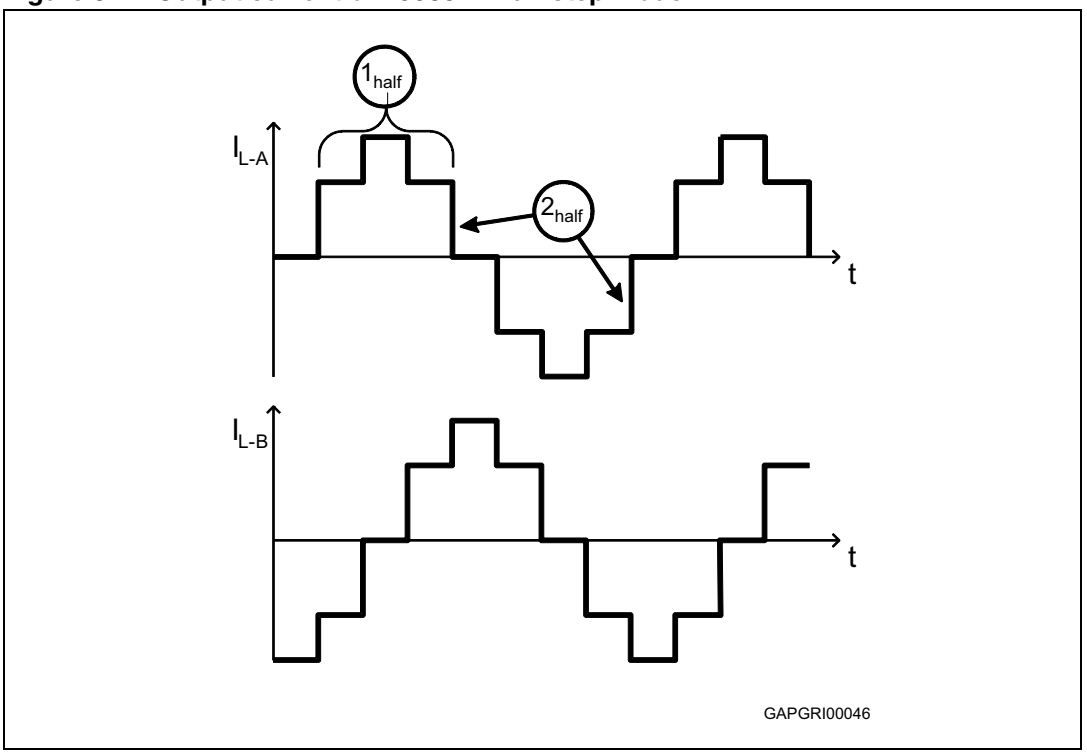
- 1_{full}: 61% I_{shunt} or 100% I_{shunt}, regulated with chopping at low-side and slow decay mode; flyback using the high-side path.
- 2_{full}: reversing the polarity of the motor coil A, using fast decay (as shown in *Figure 4*). During this polarity reversal, the flyback pulse is used for the open-load detection.

The process described above is also valid for motor coil B.

a. The symbol "I_{shunt}" in this application note is equivalent to the symbol "I_{RX}" in the device datasheet.

1.2 Half step mode

Figure 3. Output current of L9935 in half step mode



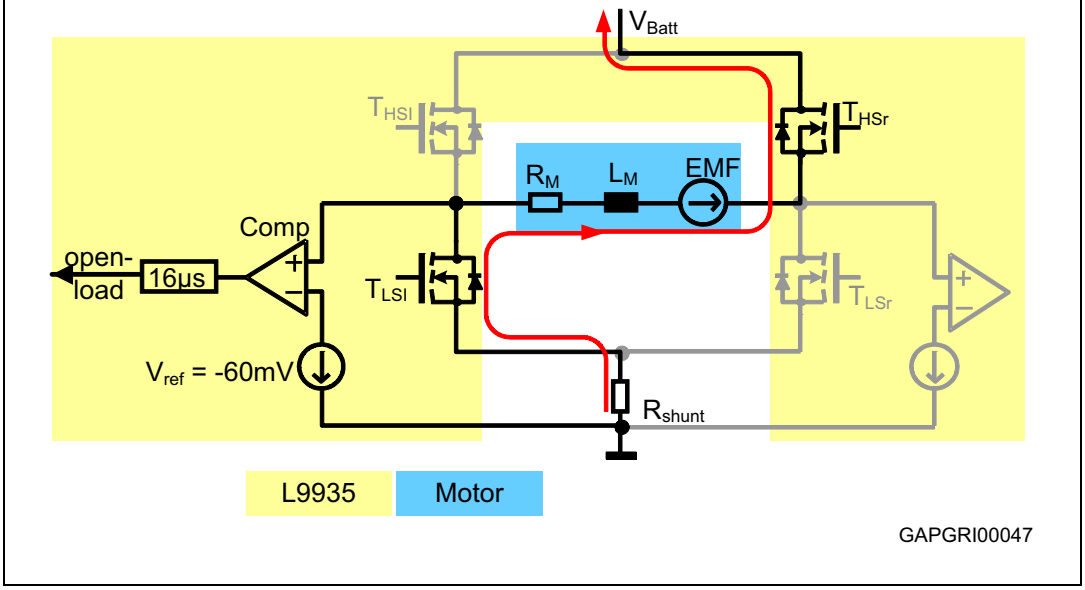
- 1_{half}: 61% I_{shunt} plus 100% I_{shunt}, regulated with chopping at low-side and slow decay mode; flyback using the high-side path.
- 2_{half}: changing from +61% I_{shunt} to –61% I_{shunt} is done in two steps, with a zero ampere current step in between. The curve to obtain 0 A in the motor coil A is used to detect the open-load, because in this step the current is free-wheeling. This step to 0 A in the motor coil uses fast decay, as shown in *Figure 4*.

The process described above is also valid for motor coil B.

2 Open-load detection of L9935

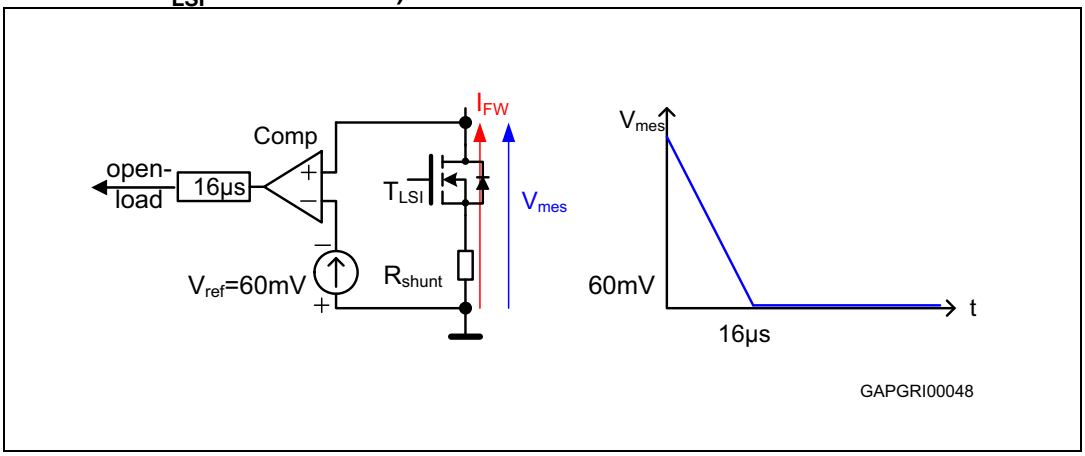
The open-load detection is done during flyback, using fast decay. The fast decay path is shown in *Figure 4*: the coil energy, stored in L_M is fed back from GND to V_{Batt}.

Figure 4. Open-load detection during free-wheeling



If the voltage drop at R_{shunt} plus $R_{DS,ON}$ of T_{LSl} does not reach the reference voltage V_{ref}, an open-load failure is detected. A failure is flagged only if the failure lasts longer than 16 µs.

Figure 5. Open-load measurement concept with simplified V_{mes} curve (if V_{mes} < 0 V T_{LSl} is switched off)



The flyback pulse is dependent on different parameters:

Equation 1

$$\frac{dI}{dt} = \frac{V_L}{L} = \frac{V_{Batt} + R \cdot I + EMF}{L} \qquad R = R_{shunt} + R_M + 2 \cdot R_{DS,ON}$$

Equation 2

$$dt = \frac{dI \cdot L}{V_{Batt} + R \cdot I + EMF} > 16\mu s$$

- Decreasing motor current leads to an increase of sporadic open-load failures.
- Increasing motor resistance R_M (temperature increase, production spread, new motor generation) leads to an increase of sporadic open-load failures.
- Increasing motor speed $\Rightarrow$ increases back-EMF (electromagnetic force) $\Rightarrow$ increase of sporadic open-load failures.
- In case of resonance effects back-EMF could be similar to V_{Batt} $\Rightarrow$ decrease of motor current “I” $\Rightarrow$ increase of sporadic open-load failures.
- In case of current regulation mode: increase of V_{Batt} $\Rightarrow$ decrease of flyback time $\Rightarrow$ increase of sporadic open-load failures.

Therefore it is not possible to directly test against a certain open-load current threshold without also defining application dependent parameters.

3 L9935 open-load production test

For testing the open-load functionality, STMicroelectronics™ uses a special go/no-go test with the parameters defined in *Table 1*. Devices that pass this test do not generate an open-load error if the load current—16 µs after going in flyback—remains higher than 90 mA.

Table 1. Production test conditions (R_{shunt} includes max 0.2 ohm contact resistance)

Parameters	ST screening test	Unit
V_{Batt}	14	V
R_{shunt}	1.2	ohm
$R_{DS,ON}$	0.4	ohm
R_{Load}	82	ohm
L_{Load}	5	mH
$I_{(t=0µs)}$	0.17	A
$I_{(t=16µs)}$	0.089	A
$V_{OUT(16µs)}$	–0.143(1)	V

1. Open-load case: the current is not regulated, that is, $I = V_{Batt}/R < I_{REG}$ and ignoring back-EMF gives the voltage over the comparator as expressed in *Equation 3*.

Equation 3

$$V_{mes}(t) = V_{Batt} * \frac{R_{DS,ON} + R_{shunt}}{R} * \left(1 - 2 * \exp\left(-t\frac{R}{L_M}\right)\right)$$

An open-load is detected if the magnitude of the flyback voltage, 16 µs after going in flyback, is less than 60 mV:

Equation 4

$$V_{mes}(t = 16\mu s) < 60mV$$

4 Open-load filter algorithm

To ensure recognition of a true open-load failure, the following algorithm is recommended:

- First of all it is helpful to separate the open-load failure from other failures. In this case the failure code has to be related to the sent data. In case of switching the output current to 0 A or inverting the current, the failure code has to be monitored. As specified in the datasheet, if the error codes 11 $\rightarrow$ 01 $\rightarrow$ 11 occur, the combination of these three error codes plus the sent command indicates an open-load error.
- Secondly, an error counter should be used. For example, all open-load failure occurrences should be counted. It should be possible to increase the functionality of the counter by resetting the counter in case of detecting a possible open-load situation **without** open-load failure.

Appendix A Further information

A.1 Reference documents

- *L9935 Two-phase stepper motor driver* (Datasheet, Doc ID 5198)

Revision history

Table 2. Document revision history

Date	Revision	Changes
19-Jun-2006	1	Initial release.
28-Feb-2011	2	Editorial and formatting changes throughout Added *Figure 5: Open-load measurement concept with simplified Vmes curve (if Vmes < 0 V TLSI is switched off)* Added *Section 3: L9935 open-load production test*

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